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Field Data Collection at Coastal Inlets

by Thad C. Pratt, Timothy L. Fagerburg, and Darla C. McVan

PURPOSE: The Coastal Engineering Technical Note (CETN) described herein provides overview guidance on the collection of field data at coastal inlets. It contains a method for planning a data collection program and identifies parameters, methods, and equipment useful for analyzing conditions at the site.

BACKGROUND: Coastal inlets are the conduits for water, material, and small waterborne animals and plants between the oceans and bays, estuaries, and lagoons. The Operation and Maintenance (O&M) activities of the U.S. Army Corps of Engineers (USACE) involve navigation channel dredging and preservation of the beaches adjacent to inlets, as well as preservation of water quality and environmental conditions (USACE Engineer Manual 1993). These activities frequently require field measurements in support of numerical and physical modeling efforts associated with inlet processes. This CETN concerns techniques and strategies for making measurements in the energetic and complex inlet environment, based on experience and developments of the Coastal Inlets Research Program (CIRP) and mission-support activities. Because each inlet has its particular combination of hydraulic processes, configuration, and engineering structures (or absence of structures), a data collection program is adapted to capture the leading parameters at the appropriate location at each inlet.

DEVELOPING A PLAN FOR AN INLET FIELD INVESTIGATION: This section gives an overview of the order of steps and associated activities in developing a data collection program.

1. Site reconnaissance. An office visit or other discussion phase will bring to light the concerns at the inlet and the general physical and engineering conditions. A site visit can then be made by those responsible for the collection effort and the local USACE staff familiar with the project. The visit will allow discussion of the past and existing conditions, define the problem, and document the area with general information on the acting physical processes and potential locations for deploying instruments.

Questions that can be addressed during the field reconnaissance include:

a. What is the local use around the problem site?

b. What studies where conducted in the region?

c. What types of construction projects have occurred at the site?

d. Are there any existing ongoing collection efforts by local agencies, universities, or other Federal agencies?

e. Are staging and deployment sites (USACE or U.S. Coast Guard equipment yards, marinas, etc.) available for preparing equipment?

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14. ABSTRACT
This Coastal Engineering Technical Note (CETN) provides overview guidance on the collection of field data at coastal inlets. It contains a method for planning a data collection program and identifies parameters, methods, and equipment useful for analyzing conditions at the site.

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f. Is there an area with power and security to power instruments and communication equipment?

g. Is there a local university near the site that might have available resources and personnel?

h. Where are the available access points for boat launches?

i. Who rents boats in the local area and are the boats suitable for data collection?

j. What kinds of structures are available for mounting instruments?

k. Where are benchmarks along the project area for leveling gauges?

l. What is the vandalism history in the area?

m. Are there local contractors available for assistance?

n. In the event of a long-term monitoring program, will seasonal weather conditions be a factor in deployment and servicing equipment?

o. Is seasonal lodging availability a concern?

p. Will biological fouling be a problem at the site?

q. How will fouling and other site conditions affect the instrument servicing frequency for long-term deployments?

During the site visit, local knowledge is obtained (by means of conversations with local community groups or individuals familiar with the inlet and from existing documentation) of the conditions that exist for various tidal and storm events. These data provide valuable insights for further defining the problem and assessing its magnitude. Specific attention must be paid to available mounting platforms in the project area. Additionally, resource use must be determined. If commercial fishing industry or tow traffic heavily navigate an area, then a different set of deployment problems must be addressed. Knowledge gained from conversations with local residents and users is valuable in trying to determine locations for instruments. Information gained from older data sets helps to determine the seasonal variability at the site. If a site has significant changes in currents, wave conditions, and wind directions, then longer data collection programs might be necessary to capture the seasonal variability.

2. <u>Inventory available data resources</u>. Data resources are identified that may be pertinent for understanding the inlet-related problem and determining feasible alternative solutions. Such resources include historical data, ongoing data collection, and potential future data collection and analysis. Examples are historical tide-gauge data (available on the web at (*http://h2o.er.usgs.gov*), historical and hind-cast wave data (*http://cdip.ucsd.edu*), aerial photography, and literature reviews and data compilations in the General Design Memorandum and related reports for the original project. Typical questions are:

a. Are there any tide or wave recorders inside the inlet?

b. Are there any offshore wave or meteorological buoys?

c. When was the last hydrographic survey run at the site?

d. Are the data available digitally?

e. Have any sediment samples been taken at or near the site?

f. Have any bed material samples been taken on the flood or ebb shoal?

g. Have any multi-beam or SHOALS surveys been run on the site?

h. Has side scan sonar been used to investigate the site?

i. Are beach profile surveys available?

j. Are there any aerial photographs available?

k. Are these photos in a digital format?

l. Have any Landsat or thematic mapper images been captured for this site over the years?

m. Has any dredging occurred at the site?

n. Who performed the dredging and where are the associated surveys?

o. What are the historical volumes removed?

p. How was the material removed and where was it placed?

q. How was the material removed?

SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) (*http://shoals.sam.usace.army.mil*) and multi-beam bathymetric surveys are sometimes available and are valuable for assessing local, as well as wide-area geomorphic changes that occur at the inlet. Navigation charts are beneficial for initial planning, but may be several years old and would ultimately require comparison with recent bathymetry data to assess the validity of the chart for further use. Most charts are not updated frequently enough to capture local changes in bathymetry at the project.

2. Inventory data needs for analyzing the problem. Following the site visit, assessments can be made of the information readily available, and a determination can be made of the types of data and level of effort that may be required to investigate the existing conditions at the inlet.

a. What data are needed to support the analysis method?

b. How are the data going to be used?

c. Who will use it?

d. To what accuracy are the data needed?

e. How will the data be processed?

f. Are some data types/locations more critical than others?

g. Are redundant gauges needed at any locations?

h. How will the data be made available to all the users?

i. Could additional data be collected for future studies that would be cost-effective?

Some of the data parameters that may be considered include tide, salinity, suspended sediment, bed material, waves, meteorological factors, tidal current, and bathymetry. Not all of these parameters need to be monitored in every study. The specific site problem will dictate the method of investigation and data needs in support of that method. A well documented reconnaissance trip will help this step. A site visit increases a basic understanding of the problems and points the engineer/scientist in the proper direction in developing further plans.

4. Select equipment to match the parameters to be measured. The parameters that are driving the conditions at the inlet and the equipment available to measure these parameters must be matched to provide a successful execution of the field investigation.

a. What period of record is necessary to capture normal conditions at the site?

b. Is it necessary to capture a storm event as a representative data set?

c. Are emergency retrieval plans for equipment necessary at the site?

d. Is there a significant seasonal variability?

e. How will aquatic fouling affect the data types necessary for this project?

f. What is the servicing period required to eliminate the effects of aquatic fouling?

g. What are the limiting battery requirements for the instruments?

h. What sample rates are needed for each parameter to support the analysis method?

i. What internal memory size is needed to accommodate the sample rate and duration period between service intervals.

j. How will the instruments be mounted?

k. Can the instruments be serviced from land?

l. Will divers be necessary to deploy, service, or retrieve the instruments?

m. Is external power available at each site?

Then equipment is matched to the period of collection and the needed servicing intervals to ensure collection of accurate and reliable data.

DATA COLLECTION EQUIPMENT: These parameters include, but are not exclusive to, tide, salinity, suspended sediment, waves, meteorological factors, tidal current, bathymetry, and bed material. Various types of data collection equipment are available to aid in collecting the necessary data.

1. Water level. Water level elevation can be recorded using solid-state electronic instruments. These instruments typically contain a strain gauge or quartz-type pressure transducer that records the absolute pressure of the water column above the instrument. The accuracy and resolution of these transducers are expressed as a percentage or fraction of the total range. Some instruments are vented to the atmosphere to compensate for atmospheric pressure. However, most instruments are not vented and, after the instrument is initially calibrated, changes in barometric pressure will appear as changes in depth. If a model that is not vented is used, an additional unit

is typically positioned in the study area to record atmospheric pressure changes. This allows water level data to be corrected for changes in the barometric pressure. Some of these instruments have the capability of measuring water temperature, conductivity, and dissolved oxygen concentrations, as well as water level elevation. The recording interval, frequency, and sampling rate vary depending on the needs of the project. When deploying tide gauges, it is essential to establish a datum to reference the changes in the water level. If the gauge cannot be leveled to a land-based vertical datum, then longer periods of record are needed to establish a mean sea level value for the site. Figure 1 is an example measurement plan showing the locations of instruments for a long-term study at Shinnecock Inlet on Long Island, NY. These locations were chosen in support of a hydrodynamic modeling study of inlet processes. All of the model boundary conditions, waves, winds, water levels and currents were measured with this instrument configuration.

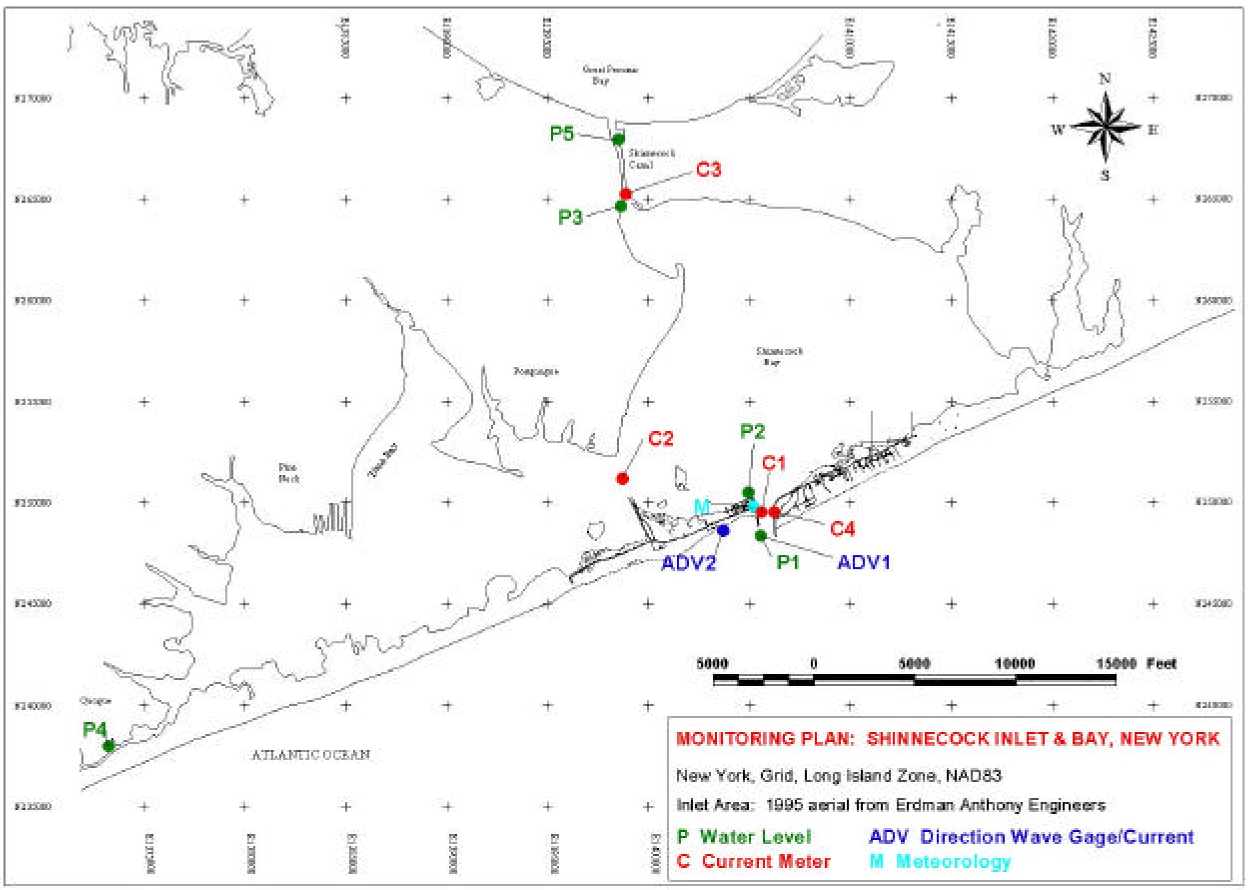

Figure 1. Shinnecock Inlet monitoring plan, Long Island, NY

The locations beginning with a "P" represent water level measurement points. The locations beginning with a "C" represent fix point current meter locations. The "ADV" locations measure water levels, currents and waves. The meteorological station was labeled "M" in this plan.

2. Salinity meters. Water quality data loggers measure conductivity and temperature and compute salinity concentrations corrected to a known calibration. This type of recorder uses a specific conductance electrode cell and a thermistor-type temperature sensor. The salinity concentrations are calculated from the measured conductivity and temperature. The range and accuracy of these recorders vary with individual instruments. The user must choose the one that will be the most appropriate for their needs.

3. Suspended sediments. Water samples for analysis of suspended sediment concentrations and total suspended solids are obtained by several methods. Niskin samplers, P61 isokinetic samplers, and pump samplers all acquire suspended sediment samples. Each method has its own set of optimal operating capabilities. The manually pumped water sample has a somewhat limited range of applicability because of the biasing that this technique has to the grain-size distribution of the sample. Typically, a pumped sample undersamples the larger grain sizes; whereas, the P61 isokinetic sampler captures a more accurate total suspended materials sample for a wider range of velocities. The Niskin sampler captures a finite volume by closing the two ends of a piece of pipe. This method might also undersample the larger grain sizes at higher flow sites. It is not been fully tested against isokinetic samplers to verify this claim.

Automatic water samplers are also available to provide unattended sampling. Water samples are collected in plastic bottles located inside the sampler body. This type of sampler is fully programmable to obtain any volume of sample up to the maximum size of the bottle, for obtaining composite samples, for setting different intervals between samples, and for setting times to begin the sampling routine.

Another method of measuring suspended sediments is by using an optical backscatter sensor. This type of sensor is designed to measure turbidity and suspended solid concentrations by detecting scattered infrared light from suspended matter. It consists of a high intensity infrared emitting diode, a series of silicon photo-diodes as detectors, and a linear solid state temperature transducer. As with other optical turbidity sensors, the response of the back-scatterance sensor depends on the size distribution, composition, and shape of particles suspended in the medium being monitored. For this reason, these sensors must be calibrated with suspended solids from the waters being monitored.

4. Wave gauges. Wave data, such as height and frequency, can be recorded using water level recorders and are similar to the tide gauges. This type of recorder uses a strain-gauge or quartz-type pressure transducer, which records the absolute pressure of the water column above the instrument. Some of these instruments are not vented to the atmosphere, and changes in the barometric pressure must be corrected. Water pressure is measured for a desired sample interval, and an average value is computed and finally stored on the data logger. These instruments should be placed in shallow water to negate damping effects caused by the absolute pressure of the water column. As with the tide gauges, recording interval, frequency, and sampling rate are set according to the needs of the project.

Wave followers or buoy gauges are also available to obtain wave data. These instruments are tethered to the bottom by means of an elastic shock cord. The buoy follows the waves by floating on top of the water surface. Accelerometers measure the motion of the buoy as waves

pass. The directional wave follower contains a flux-gate compass to determine the direction of the wave by measuring the orientation of the buoy to true north. Therefore when displacements are measured with the accelerometers, a direction component to the wave motion can be calculated. Non-directional wave followers measure heave, pitch, and roll with accelerometers.

Some companies have incorporated velocity and pressure measurements into instrument packages to obtain wave direction and amplitude data. These instruments can capture wave motion in and around structures, whereas the wave follower/buoy gauge is more applicable offshore. Newer acoustic instruments being produced measure waves and currents throughout the water column. All of these instruments have specific areas where they perform better. The user will have to consult the manufacturer's literature for the best model for the application according to rapid advancements in the instrument industry. Figure 1 also shows where the wave data was collected for this study.

5. Weather stations. Meteorological data, such as wind speed and direction, precipitation and evaporation, temperature, relative humidity, and barometric pressure, are recorded by weather stations. The weather station should be located at some central location in the study area and, following American Meteorology Society standards, mounted approximately 10 m over land. No standards have been established for mounting weather stations over open water; however, depending on the meteorological parameters being monitored and their purpose, the weather station should be mounted approximately 2 to 3 m above the highest wave height during a storm. There are numerous types of weather equipment that can meet the requirements for the project depending on the accuracy of the instrument. Self-contained weather stations use a battery-powered microcomputer with a real time clock, a serial data interface, and programmable analog-to-digital converter. The battery is constantly charged by a solar panel-charging system located near the system. Various programming options are available to set the sampling interval and averaging period. The system can be programmed to sample input signals each second over a set period of time to determine the mean, maximum, and minimum values of the various parameters.

6. Current meters. Acoustic techniques are used to obtain current velocity and direction measurements for fast and accurate profiling in the field. The Acoustic Doppler Current Profiler, ADCP and Acoustic-Doppler Profiler (ADP) transmit sound bursts into the water column, which are scattered back to the instrument by particulate matter suspended in the flowing water. The ADCP and ADP sensors listen for the return signal and assign depth and velocity to the received signal based on return time and the change in the frequency caused by the moving particles, respectively. This change in frequency is referred to as the Doppler shift. The ADCP is also capable of measuring vessel direction, current direction, water temperature, and bottom depth. Communications with the instrument for setup and data recording are performed with a portable computer using manufacturer-supplied software, hardware, and communication cables. The instrument can be mounted over the side of a boat with the acoustic transducers submerged. The data are collected while the vessel is underway. Both ADCP and ADP can be mounted on a stable platform and placed on the bottom of the river or ocean. Self-contained recording point current meters are used to obtain long-term fixed-depth data. This type of current meter is tethered to a stationary line or structure. The measurement method can range from electromagnetic to acoustical. An internal microprocessor computes the velocity vectors, which

are stored in solid-state memory. Cost, accuracy, performance, and reliability must be weighed in selecting the optimal instrument for the location. Figure 2 shows example transect line locations for the intensive surveys at Shinnecock Inlet. These locations for the short-term intensive survey capture the hydraulic processes at the inlet during a tidal cycle. These data provided the necessary information to calibrate and validate the numerical model performance at the site.

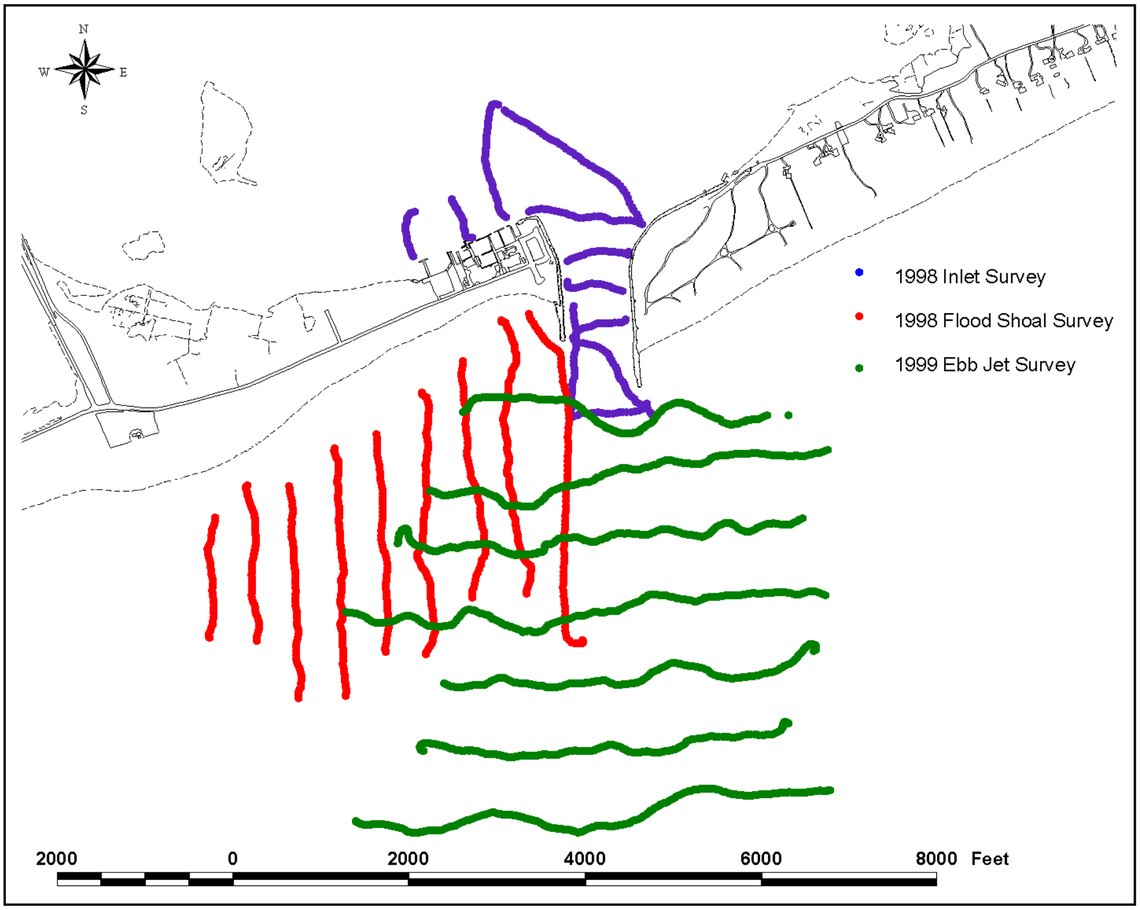

Figure 2. Transect line locations at Shinnecock Inlet, NY

Each survey was designed to look at specific areas of interest. The 1998 survey was designed to capture inlet processes throughout a tidal cycle, whereas the 1999 survey confirmed phenomena predicted by a numerical model. The 1999 data were collected during an ebb cycle to observe the movement of the ebb jet and the development of large-scale eddies.

7. Bathymetric survey. Acoustic depth sounders, such as the 200-kHz echo sounders, measure the travel time of an acoustic pulse from a generating transducer to the waterway bottom and back. The travel time of the reflected wave is converted into distance. The instrument must be calibrated daily to account for electronic drift and speed of sound changes in water. Other methods include a variety of multiple-transducer channel-sweep systems, single-transducer multi-beam swath systems, and manual depth measurements. The most commonly used manual

methods are the lead line or sounding disk measurements and the sounding pole. The compilation of bathymetric data can be somewhat complicated; criteria and present policy and guidance that the USACE uses for performing hydrographic surveying can be found in USACE EM 1110-2-1003 (1994). The channel-sweep systems are simply a series of standard 200-kHz transducers mounted on booms that are lowered over the side of the boat. These systems are designed to provide 100 percent coverage over a given width or swath. To capture 100 percent coverage of the project site, the boat must run lines that overlap. Most Districts where fluid mud is present in the channel and surrounding areas perform surveys with dual frequency echo sounders. A dual frequency echo sounder transmits by 24- and 200-kHz transducers. Another technique to measure the fluid mud layer is called the Towed Density Follower (TDF). The instrument follows a specific density layer to map the navigable depth in a channel. The shape and density of the instrument enable it to follow the desired density layer. Data is transmitted through a cable to the surface where it is input into the hydrographic survey package as a generic fathometer signal.

8. Multi-beam swath systems. The multi-beam swath systems employ phased array or interferometric techniques from a single point, from which detailed terrain cross-section data can be developed many times per second. This technique can provide detailed, high-resolution bathymetry data.

The USACE has developed surveying technology known as SHOALS. SHOALS is a helicopter-mounted system that uses Light Detection and Ranging (LIDAR) technology to collect bathymetric data in the coastal zone. For more information visit (*http://shoals.sam.usace.army.mil)*. This technique is efficient for surveys over large areas and exceeds the capabilities and efficiency of traditional survey methods. This technique is applicable in shallow water (depth less than 10-20 m depending on water clarity) without a high-suspended sediment load. SHOALS can collect data in areas that are normally too shallow for standard methods. Figure 3 is an example of SHOALS data taken at an inlet. The contours and color shading were developed inside the HyPAS GIS System (Pratt and Cook 1999).

1. Bottom sediment sampling. Depending on project objectives, the USACE requires many different types of bottom sediment samplers ranging from large-volume samplers taken from a fixed platform to smaller over-the-side samplers easily operated from a small vessel.

   a. Vibracore samplers typically require a stable platform to capture the samples. This method is used when deeper core samples are needed to classify the underlying bed material. This method of sampling and the analysis of the samples are usually expensive, so the need and the quantity of the samples must be weighed against the cost of the samples.

   b. The push-core sampler consists of a 1.5-in.-diameter PVC pipe, 18-in. in length. Attached to this is a smaller section of pipe with a valve attached at the upper end. The purpose of the valve is to create a reduced pressure holding the sample in the larger-diameter pipe. The samples are then brought to the surface and classified by visual inspection or sent to a laboratory for more detailed analysis.

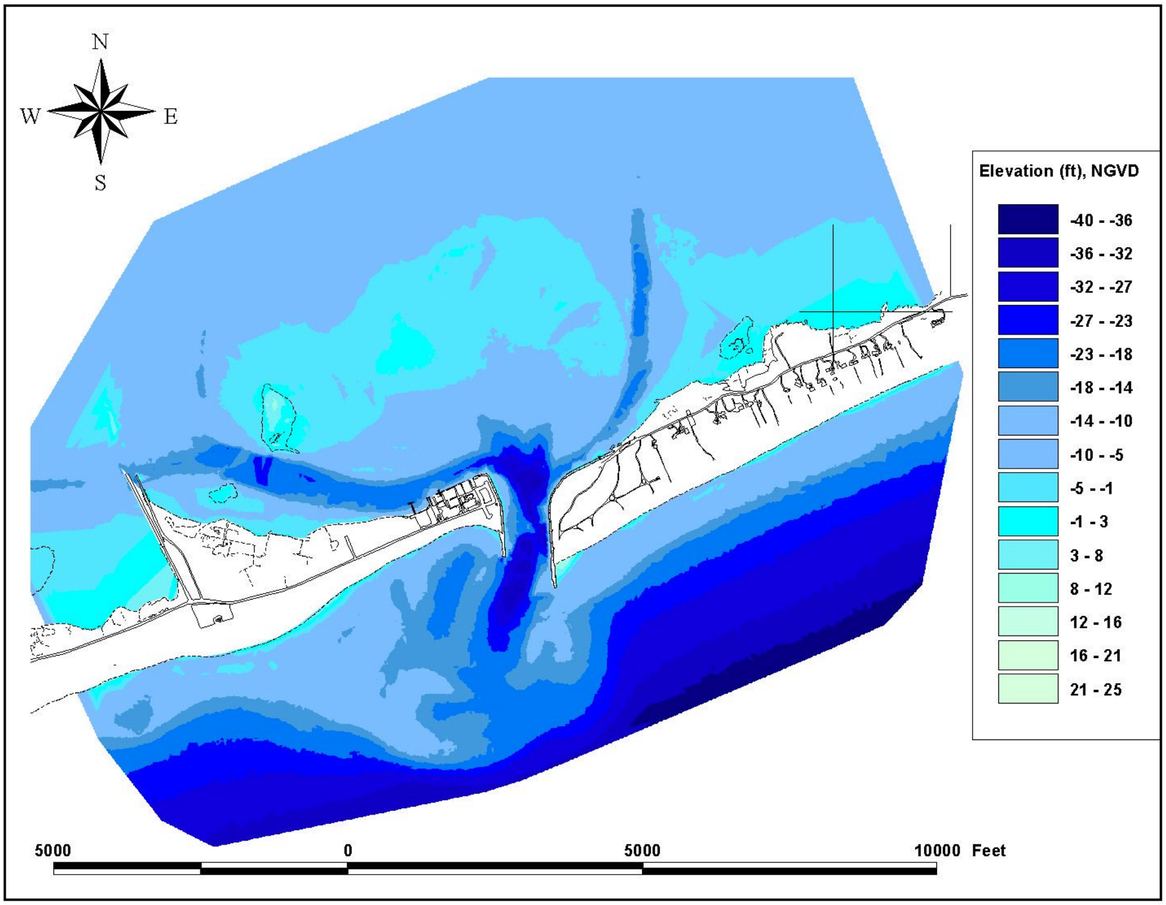

Figure 3. SHOALS bathymetric survey at Shinnecock Inlet, NY

c. The petite Polar sampler is a clamshell-type sampler. This type of sampler is cocked on the surface before lowering to the bottom. When the sampler makes contact with the bottom, the trigger pin releases allowing the sampler to close. As the sampler is raised to the surface, it remains closed around the captured sediment until it is opened at the surface. The samples are removed, inspected, and packaged in plastic bags or jars for further analysis.

d. The box-core sampler is similar to the petite Ponar in its triggering mechanism and sampling technique. The main difference in the two is where the sample is trapped. The box-core sampler has clamshell jaws that scoop the sediment into a clear plastic square tube. When the sampler is opened at the surface, the sample is visible from a top door on the sampler. From this door, the sample can be subsampled for more detailed analysis.

e. The tethered-drag (bucket dredge) sampler is basically a 3-in.-diameter pipe cut on a 45-deg angle with a shackle mounted on one side. The sampler is thrown over the side and dragged along the bottom and the sample accumulates inside the pipe. The samples are then removed, inspected, and packaged in plastic bags or jars for further analysis.

Once the method of sampling is chosen, a sampling scheme must be laid out to best define the needed information for the site. Figure 4 represents a bed material sampling scheme as carried out at Shinnecock Inlet, NY. This scheme was extensive to define all the different types of material and material properties at the inlet, which runs through glacial sediments of varied types. The number of samples and the coverage conform to project requirements. Accurate positioning for repeatable collection at the predetermined locations can be achieved by using a Differential Global Positioning System (DGPS) and navigation software.

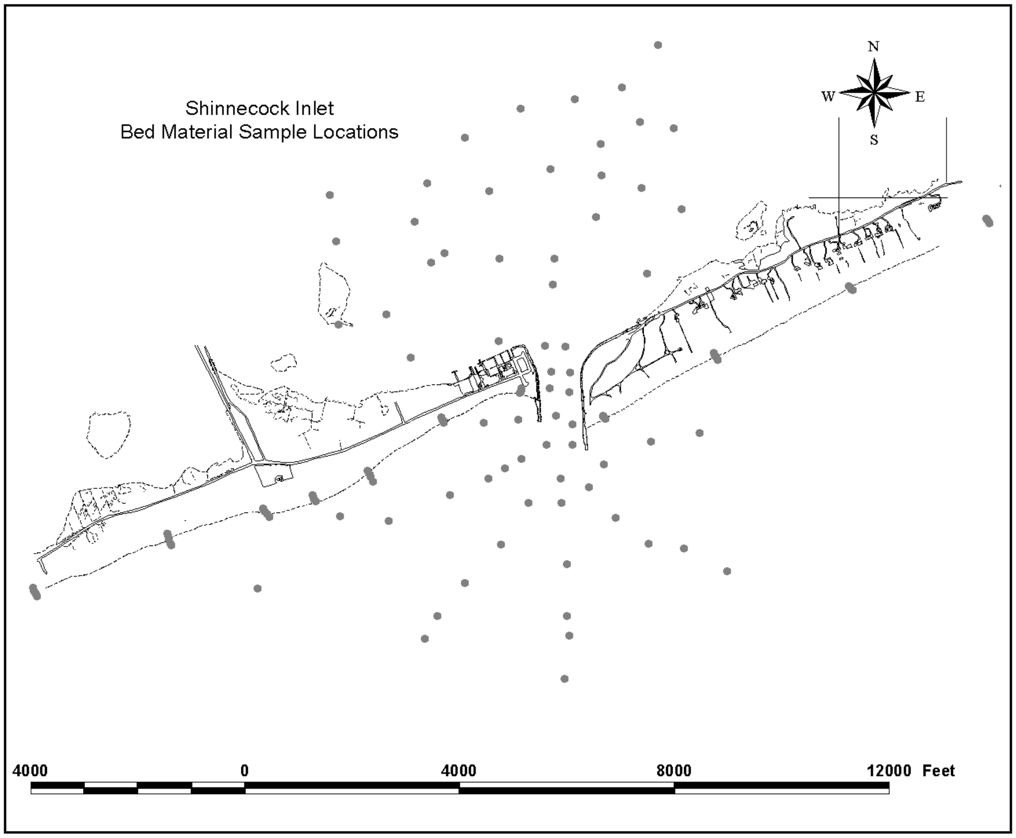

Figure 4. Bed Material Sampling Scheme at Shinnecock Inlet, NY

10. <u>Side-scan sonar (SSS)</u>. The SSS is deployed in reconnaissance and search applications such as exploration, identification of bottom material, and navigational hazard mapping, and similar applications. The SSS is capable of penetrating water too turbid for visual or optical inspection, which makes it an effective tool in many environments. Its real-time display allows for onsite decisions on data collection modifications; SSS is relatively fast and cost-effective, especially for large-scale surveys. The SSS system includes a tow fish and cable and a control power unit which processes, displays, and records data. The signals are transferred through an electrical cable, which can also serve as the towing line, to the control unit and are then displayed in real-time and stored.

SUMMARY: Considerable data-collection equipment and types of instruments are available to measure the numerous parameters that may exist at a coastal inlet project. Upon completion of a field reconnaissance, the data requirements, level of effort, and instrument locations can be determined. The appropriate instrument can be chosen based on the performance requirements for the site, accuracy needs of the study, servicing requirements for the deployment, and budgeting restrictions associated with the total project.

ADDITIONAL INFORMATION: For further information, contact Mr. Thad C. Pratt (Voice: 601-634-2959, e-mail: *prattt@wes.army.mil*) or Mr. Tim Fagerburg (Voice: 601-634-2257, e-mail: *fagerbt@wes.army.mil*), U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. For information about the Coastal Inlets Research Program, please contact Dr. Nicholas C. Kraus (Voice: 601-634-2016, e-mail: *krausn@wes.army.mil*). Any mention of a commercial product does not constitute an endorsement by the Federal Government. This CETN should be cited as follows:

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